An Examination of 3D Environmental Variability on Broadband Acoustic Propagation Near the Mid-Atlantic Bight

Kevin B. Smith
Code PH/Sk, Department of Physics
Naval Postgraduate School
Monterey, CA 93943
phone: (831) 656-2107 fax: (831) 656-2834 email: kevin@physics.nps.navy.mil
Award #: N0001498WR30122

LONG-TERM GOAL

Under the PRIMER initiative, the Office of Naval Research sponsored a multi-year study of acoustic propagation in the region of the North Atlantic Bight off the coast of New Jersey. This region is of interest due to the combination of sloping bathymetry near the continental shelf and the strong oceanographic frontal features associated with the Gulf Stream. The general purpose of this project is to study the effects of the frontal region on acoustic propagation onto the shelf. Proposed here is a complementary study of propagation effects and data analysis. Specifically, the influence of three-dimensional propagation effects and their influence on the prediction of broadband measurements in similar oceanographic regions shall be addressed. Studies of two-dimensional, broadband propagation will also be performed to examine temporal variability of plane-wave beam arrivals. Attempts will be made to invert for geoacoustic parameters using both broadband ambient noise data and explosive SUS data.

OBJECTIVES

To continue analysis of the PRIMER summer '96 acoustic data. This analysis will primarily focus on the influence of 3-D azimuthal coupling due to bathymetric features and ocean fronts near the shelf break of the mid-Atlantic Bight, plane-wave beam variability through a fluctuating front with non-linear soliton wave activity, and use of various data for geoacoutic inversion studies. The results of this analysis will provide guidance for the use of active and passive sonar systems near shelf break regions.

APPROACH

In FY98, I continued my analysis of the Primer summer 96 data sets. As before, issues to be considered included the influence of 3-D propagation on measured acoustic transmissions, both CW and broadband. The dominant mechanisms responsible for such azimuthal coupling were identified and quantified. Signatures of such effects in the data were scrutinized.

The temporal and spatial variability of arrival angles (computed using standard plane-wave beamforming techniques) were analyzed. This analysis focussed on the 400 Hz tomo data received on one of the VLA's over the course of the experiment.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE **An Examination of 3D Environmental Variability on Broadband Acoustic Propagation Near the Mid-Atlantic Bight**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Postgraduate School,Department of Physics,Monterey,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

In addition, analysis was performed in an attempt to invert for various geoacoustic properties in this area. Specifically, by using information from ambient noise correlations between hydrophones, an estimate of the sediment sound speed was made (Buckingham and Jones, 1987). Then, by determining the modal effective depth of an ideal waveguide, one may deduce the sediment density (Chapman et al., 1989). The combination of these approaches were attempted on the data taken during the SUS runs. Results were compared with historical geoacoustic data sets and with the inversion values computed by Prof. James Miller at URI (using a propagation model with a genetic algorithm approach).

WORK COMPLETED

Numerical analysis of significance of 3D propagation influences for this experimental configuration has been completed.

Data analysis of 400 Hz tomography source along the SW to NW leg have been performed for evaluation of signal variability. The average of the 5 minute PRN signal, reccurring every 15 minutes, was used for this analysis. Shorter time variability was not available for evaluation.

Numerical and data analysis of ambient noise data and SUS signals for purposes of geoacoustic inversions have been completed for some data sets.

RESULTS

The numerical analysis showed that the dominant mechanism for 3D azimuthal coupling in this region was the sloping bathymetry. However, even this effect was quite small and may be considered insignificant relative to the uncertainty in determining the environment. The dB difference in arrival time structure with and without 3D effects along the SW-NE track is depicted in Figure 1. Other propagation paths not measured in the experiment may provide larger effects and are currently being considered.

The signal variability was found to be quite high on individual hydrophones with low correlation values of ~ 0.5 between subsequent PRN transmissions from the tomography source. Similar low correlation values were found for several beams. Examples of this are shown in Figures 2 and 3.

Figure 4 displays the signal variability on the center phone over a 3-day period during the experiment. While the variability is high, there are semidiurnal trends which are consistent with tidal motion of the front. A reasonable estimate of the horizontal displacement of the front due to tidal motion was determined to be ~ 10 km (Sullivan, 1997).

The use of vertical noise correlations to determine bottom sound speed worked well, providing an average speed of 1563 +/- 10 m/s (Smith, et al., 1998). For the spectrum of noise used, this may be considered an average of the bottom sound speed in the upper ~ 10 m. This value agrees well with AMCOR data and the results obtained by Prof. Jim Miller of URI who used genetic algorithm search techniques to localize the bottom geoacoustic parameters.

The use of the effective mode depth to determine bottom density did not work with the available SUS data due to a lack of signal resolution. Improvements to the technique and appropriate types of sources for use with such techniques are being considered for future work.

IMPACT/APPLICATION

The lack of significant azimuthal coupling effects observed is an important conclusion. This suggests that 2D propagation models, and the sonar prediction systems based on such models, are satisfactory. There appears to be no need to upgrade current systems to account for 3D propagation effects. This is fortunate since such 3D models are known to be much more computationally intensive than their 2D counterparts. However, it was also shown that signal variability is quite high in shallow water regions, which could impact the performance of sonar prediction systems. Finally, it was found that simple inversion techniques can provide some information on the geoacoustic parameters of the seafloor.

RELATED PROJECTS

1 - Ching-Sang Chiu (NPS) and Jim Lynch's group (WHOI) are also studying the acoustic signal variability caused by the front and associated soliton wave activity.

2 - Jim Miller (URI) is also studying methods for geoacoustic inversion using genetic algorithm techniques applied to the SUS explosive data.

REFERENCES

Buckingham, M. J. and Jones, S. A. S. (1987). "A new shallow-ocean technique for determining the critical angle of the seabed from the vertical directionality of the ambient noise in the water column," J. Acoust. Soc. Am. 81(4).

Chapman, D. M. F., Ward, P. D., and Ellis, D. D. (1989). "The effective depth of a Pekeris ocean waveguide, including shear wave effects," J. Acoust. Soc. Am. 85(2).

Sullivan, J. L. (1997). "Analysis of Acoustic Plane-Wave Variability in the Region of the Mid-Atlantic Bight Shelf Break," Master's Thesis, Naval Postgraduate School, December, 1997.

Smith, K. B., Rojas, J. G., Miller, J. H., Potty, G.-P. (1998). "Geoacoustic Inversions In Shallow Water Using Direct Methods And Genetic Algorithm Techniques," Proceedings of the Pacific Ocean Remote Sensing Conference (PORSEC'98), 21-24 July, 1998, Qingdao, China.

PUBLICATIONS

Smith, K. B., Rojas, J. G., Miller, J. H., Potty, G.-P. (1998). "Geoacoustic Inversions In Shallow Water Using Direct Methods And Genetic Algorithm Techniques," Proceedings of the Pacific Ocean Remote Sensing Conference (PORSEC'98), 21-24 July, 1998, Qingdao, China. (Invited talk.)

Smith, K. B., Chiu, C.-S., Miller, J. H., Lynch, J. F., and Gawarkiewicz, G. G. (1997). "Three-dimensional propagation effects near the Mid-Atlantic Bight," J. Acoust. Soc. Am., Vol 102 (5), Part 2, pg. 3143.

Smith, K. B. (1998). "Three-dimensional propagation effects: Modeling, observations, and suggested benchmark cases," J. Acoust. Soc. Am., Vol 103 (5), Part 2, pg. 2989. (Invited talk.)

Sullivan, J. L. (1997). "Analysis of Acoustic Plane-Wave Variability in the Region of the Mid-Atlantic Bight Shelf Break," Master's Thesis, Naval Postgraduate School, December, 1997.

Rojas, J. G. (1998). "Geoacoustic Inversion Using Direct Methods on Ambient Noise and Explosive Data in a Shallow Water Waveguide," Master's Thesis, Naval Postgraduate School, March, 1998.

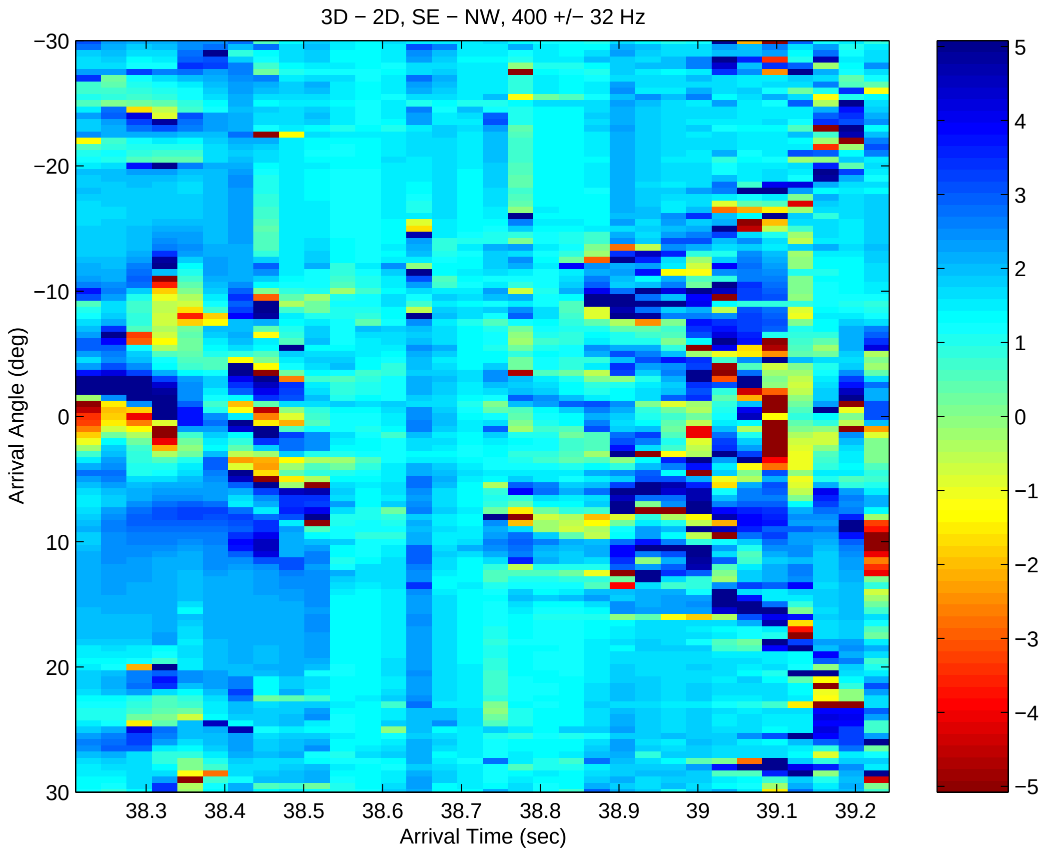


Figure 1. Arrival angle versus arrival time signal differences (dB scale) between full 3D calculation and 2D calculation. Maximum values ~ +/- 5 dB. Note that the maximum differences occur in the weakest portions of the pulse arrival (very early and very late in the signal), and the dominant portion of the arrival (between 38.5 and 38.9 secs) show typically less than ~ 2 dB difference.

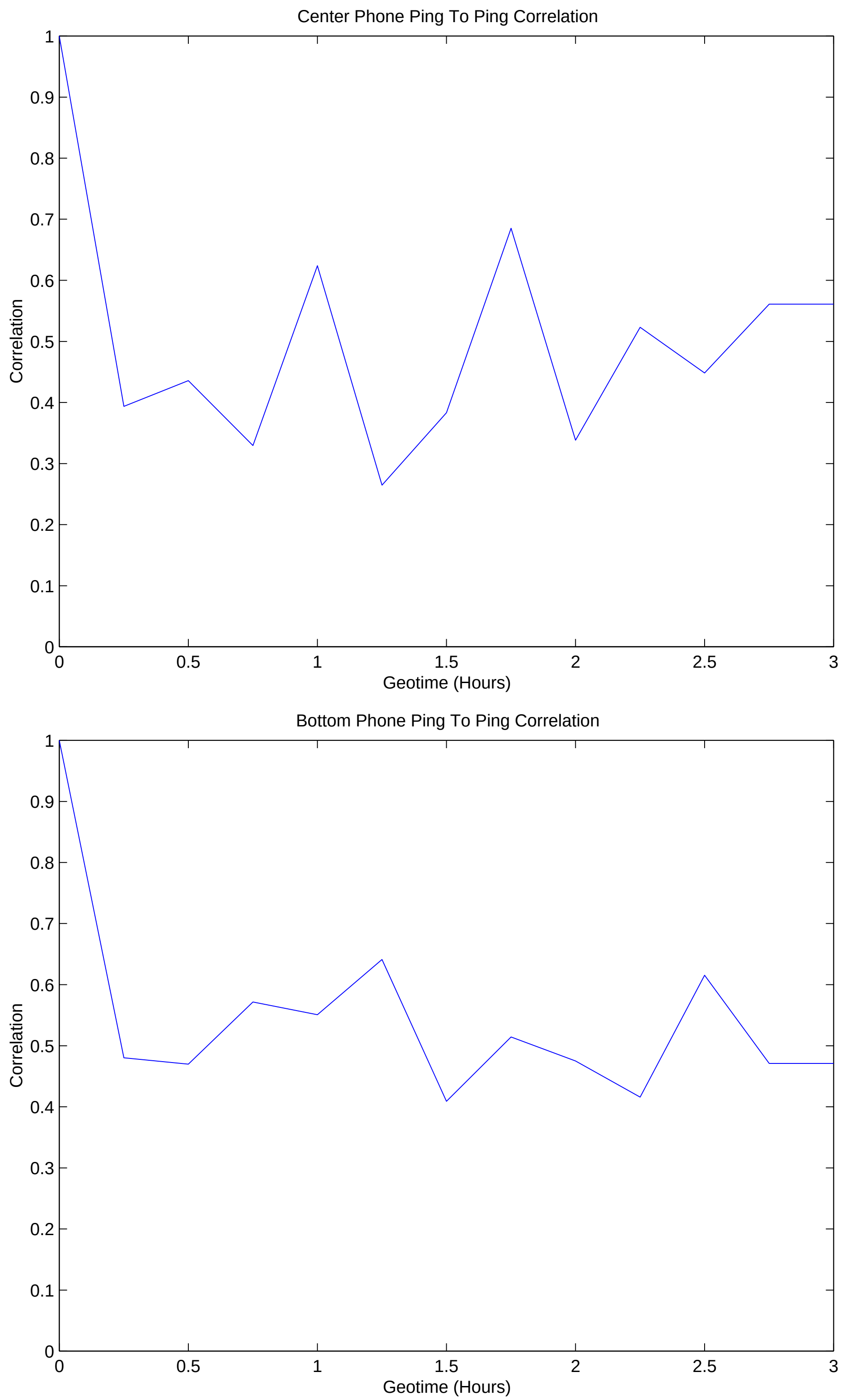
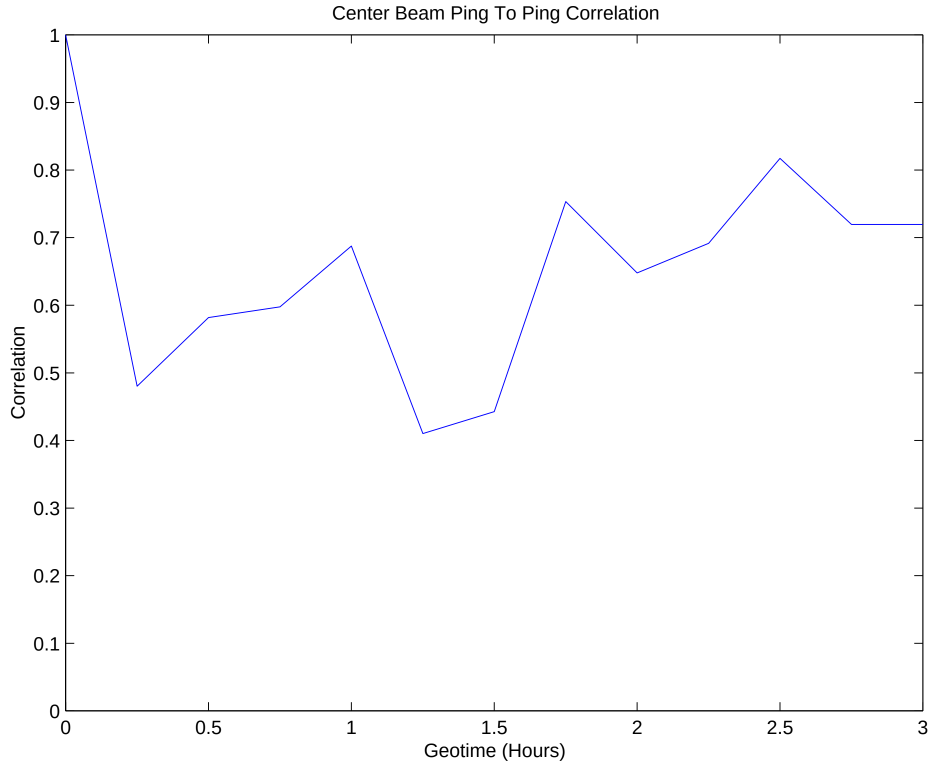


Figure 2: Ping to ping peak correlation of the center and bottom phones over a 3-hour period.



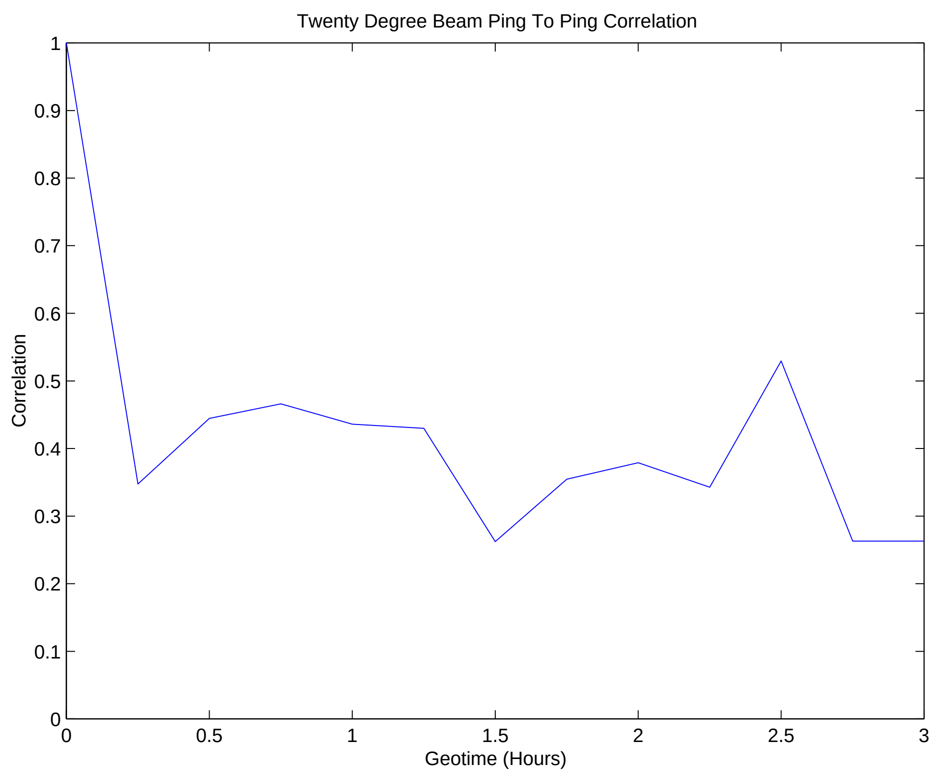


Figure 3: Ping to ping correlation of center beam and 20^{o} beam over a 3-hour period.

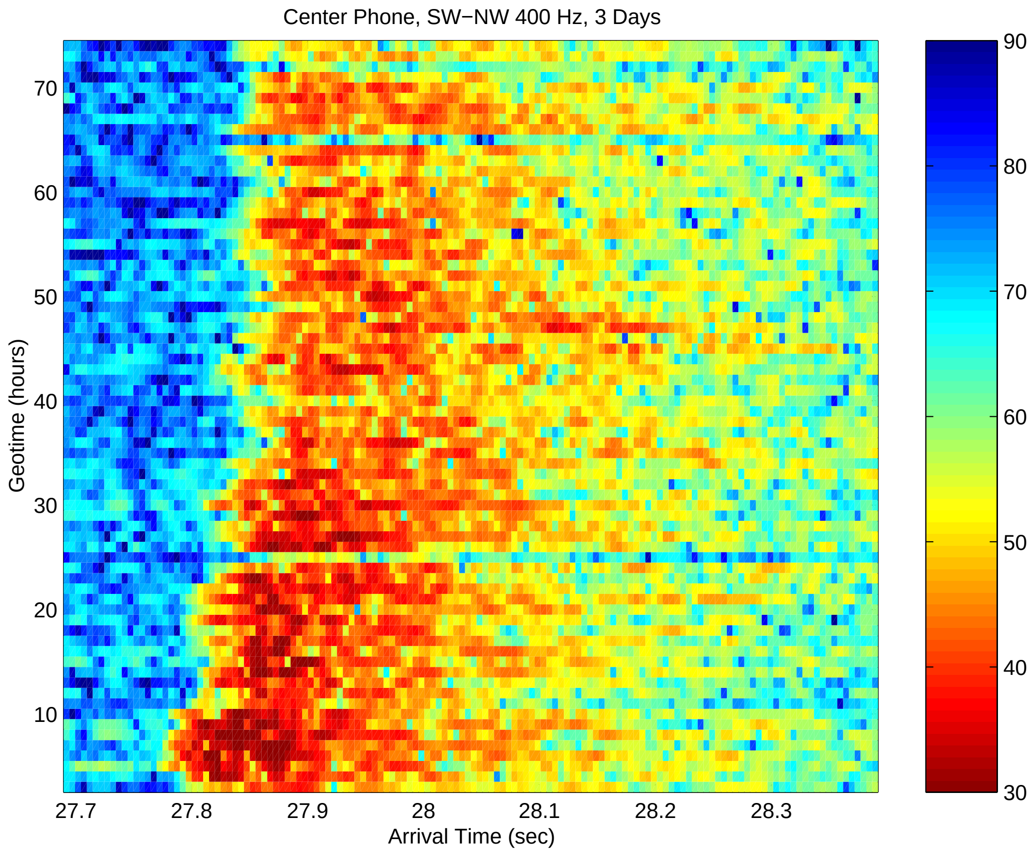


Figure 4: Geotime versus arrival time display of arrival structure for center phone over a 3-day period.